Geosensing Ship Activity to Estimate Invasive Species Risk

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Introduction

• Motivation:
  • Policy
  • Technology
  • Risk-based approach

• Model Overview:
  • Vessel ballast and hull conditions
  • Trade routes
  • Ecosystem similarity
  • Environmental organism profiles (eDNA)

• Application:
  • Visualization of routes
  • Case study designs for prospective changes
  • Expanded research collaboration
Ranges and scales of economic impact assessments

- US aquatic invasive species: $9 B/yr
- US all invasive species: $120 B/yr
- Worldwide all types: $1.4 T/yr
  
  Pimental et al, various publications

- Great Lakes: $200 M/yr
  
  Lodge et al, various publications

- Commercial Fishing: $2,117,000
- Raw water users: $27,000,000
- Wildlife Watching: $47,659,000
- Sport Fishing: $123,553,000

Estimate of loss consumer surplus: $200,329,000
Motivation

• Policy: IMO Ballast Water Convention, US Clean Water Act
  • IMO BWM nearly in force, set treatment standards, later adopted by US
  • UPDATE I: US 2nd Circuit Court of Appeals, standards not technology forcing
  • UPDATE II: HR 4909 may exempt ballast water discharges from Clean Water Act

• Technology
  • Dozens of treatment systems “certified” under IMO type approval process
  • USCG type approval process – no technologies yet approved (~3 dozen LOIs)
  • New technologies remotely cleans hulls and removes waste to surface

• Risk-based approach
  • Option to employ measures everywhere may be inefficient, ineffective, or both
  • Invasive risk changes with shipping technology, vessel traffic, and trade patterns
Model Overview

Human Systems

Spread of Nonindigenous Species (NIS)

Coastal Ecosystems

Ecosystem Services

Policies

Shipping Network

Global Trade
GIFT Global Freight Transport Model

GTAP Global Trade Model

Production Factors (ie. land, labor, resources, transportation costs)

Inputs from other Sectors

Household Consumption

Optimized Sector Production

International Trade Dependent on Relative Prices & Tastes

Monetary payments

Goods & services

Ship Traffic

NIS-RAPS Input

Export Ratios

NIS-RAPS Input
Application

Origin-Destination Overlay
Growing or shifting trade routes merit study

TPP risks identified: “... localized environmental impacts at selected U.S. ports...”
Growing or shifting trade routes merit study

Example: Delaware Bay Port Pairs with other Global Gateways
TPP risks identified: “... introduction of invasive species...”


Clusters are groups of ports that are “tightly-coupled” due to species flows (NIS-RAPS)

**Trade patterns**, technology, vessel behavior, ..., evolve over time

Changes in the species flow network modify the species flow risk of invasions.

TPP risks identified: “... introduction of invasive species...”

Higher-order networks can better capture complex ship movement patterns and yield overlapping clusters, highlighting ports that may be susceptible from different sources of invasions.
Risk of arrival and establishment of nonindigenous species from Singapore

Ballast-invasive risk appears to be a positive function of:
- # voyages by given ship type
- mean ballast discharge by ship type
- different ecoregion
- environmental similarity (salinity, temp)  

(Xu et al. 2014)
Arctic case study design?

• Key nations in case study of opening sea ice:
  China, USA, Spain, Malaysia, Thailand, Indonesia, South Korea, Australia, Canada, Taiwan, Norway, Japan, Egypt, Italy, Denmark, Great Britain, 26 others

• Current status: very few current routes connecting through Arctic Ocean (quantify)
  • Case 1 (Status quo): Compute NIS connectivity risk for current observation(s)
  • Case 2 (Arctic museum): “turn the cross-Arctic routes off”
  • Case 3 (Arctic frontier): increase connectivity – maybe new trade, more trips
Current Day Scenario

~1000 routes crossing Arctic

Green: “current day” routes
Ave Distance: ~16.7k KM

Orange: “avoid Arctic” routes
Ave Distance: ~18.3k KM

Light blue: “open Arctic”
Ave Distance: ~17.2k KM

Ice sheet September 2012 and Sept median 1981-2010

NIS risk ↑ or ↓?
Thank you

Discussion welcome ...

... collaboration invited

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